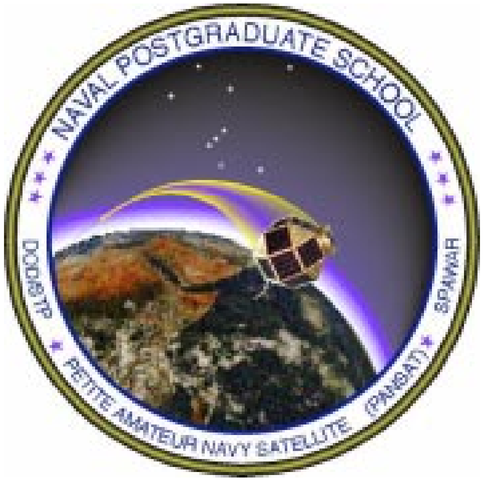
PANSAT Functional Testing Software and Support Hardware


NAVAL POSTGRADUATE SCHOOL
DOD/STP
SPAWAR
PETITE AMATEUR NAVY SATELLITE (PANSAT)

INTERNATIONAL EXTREME ULTRAVIOLET HITCHHIKER
IEH
3
STARLITE•SEH•CONCAP IV•NASA GSFC•PANSAT•UVSTAR•SOLCON

Sep. 1999

Mr. Jim A. Horning, Naval Postgraduate School

1999 Shuttle Small Payloads Project Office Symposium

PANSAT Functional Testing Software and Hardware

- Introduction
- Support for Prototyping
- Electronic Modules Architecture
- Prototype Hardware and Software
- Spacecraft Hardware and Software
- Spacecraft Integration
- Conclusion

Introduction

- Designed and built at NPS
- Required easy functional testing
- Used COTS equipment to build the digital hardware interface prototypes
- Reused software test components
- Used simple support hardware

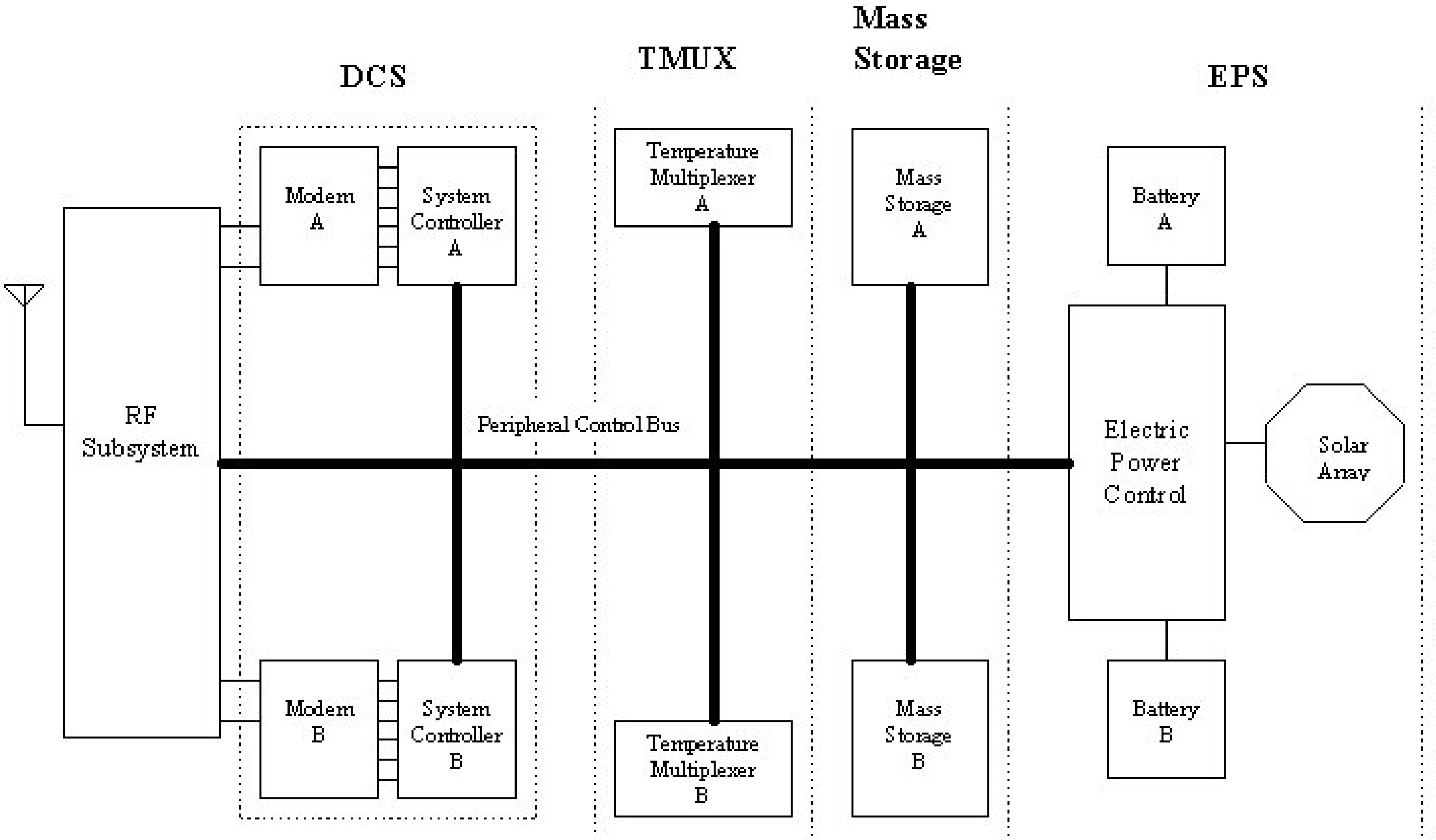
Support Equipment for Development

- PC:
    - IEEE-488 (GPIB) interface card
    - National Instrument’s ATMIO-16
        - multiple analog inputs
        - 4 programmable digital lines
    - National Instrument’s LabVIEW® for programming
- Programmable Power Supply (HP 6653A)
    - connected to the GPIB
- Programmable Load (HP 6060A)
    - connected to the GPIB
- In-circuit Emulator
    - supported embedded software development

Software Tool for Prototyping

- LabVIEW
  - Provided graphical programming in the form of block diagrams
  - Learned quickly and easily
  - Offered sophisticated graphical user interfaces with no programming
  - Allowed simple translation from engineer’s concept to program
  - Simplified the porting of the prototype software to the embedded system of the spacecraft flight hardware

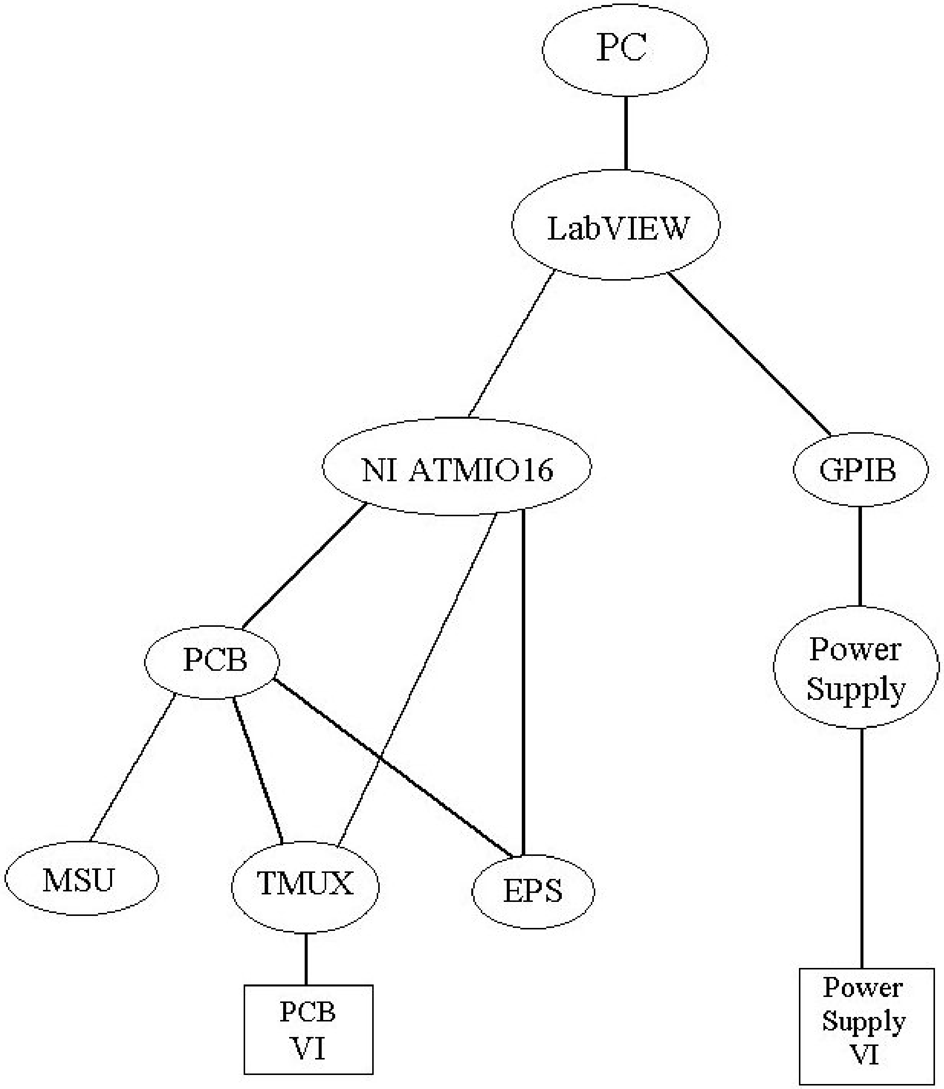
Electronic Modules Architecture



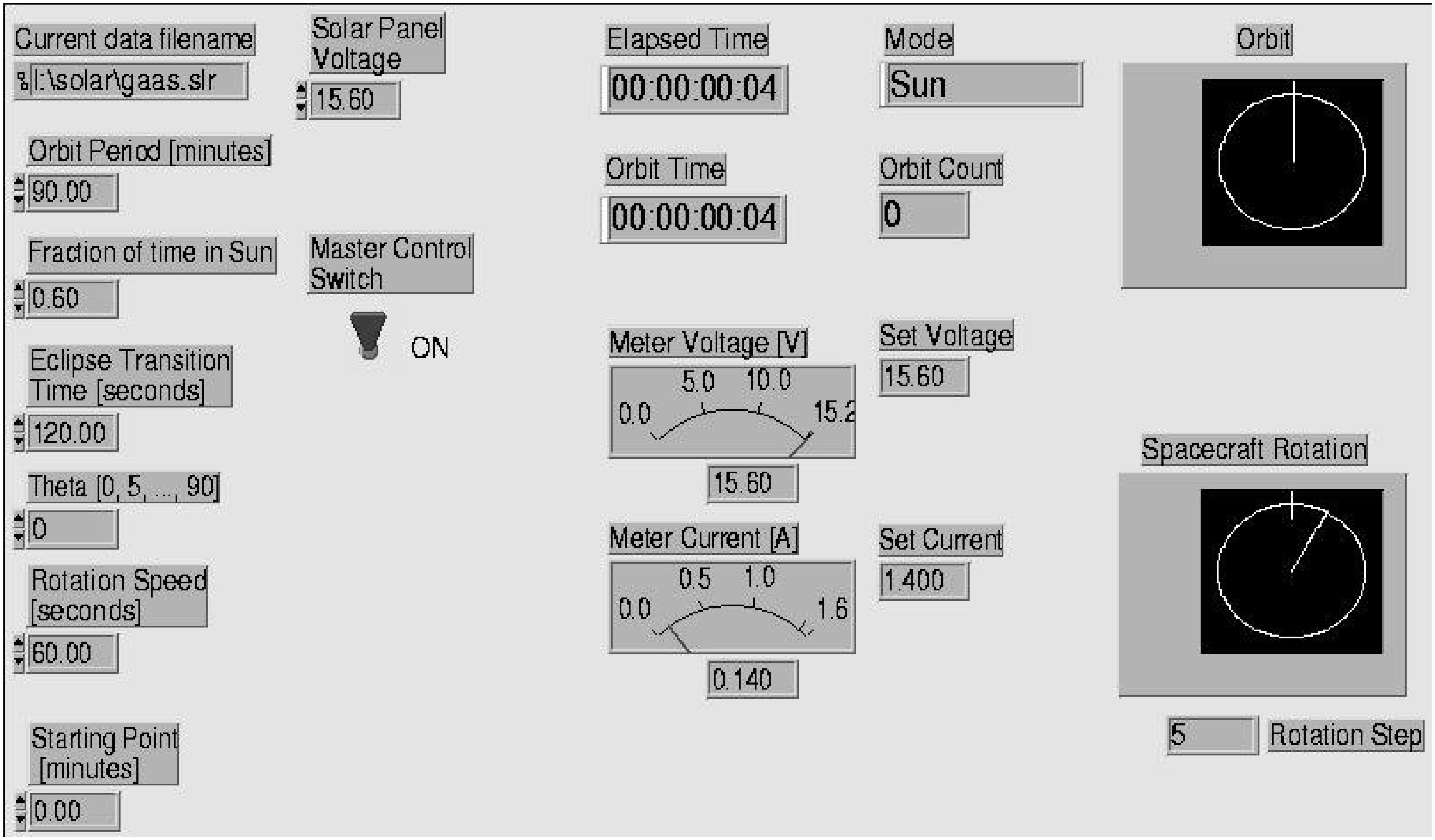
Mr. Jim A. Horning, Naval Postgraduate School

1999 Shuttle Small Payloads Project Office Symposium

Prototype Support Hierarchy



Solar Simulator VI



Current data filename
I:\solar\gaas.slr

Solar Panel Voltage
15.60

Orbit Period [minutes]
90.00

Fraction of time in Sun
0.60

Master Control Switch
ON

Eclipse Transition Time [seconds]
120.00

Theta [0, 5, ..., 90]
0

Rotation Speed [seconds]
60.00

Starting Point [minutes]
0.00

Elapsed Time
00:00:00:04

Orbit Time
00:00:00:04

Mode
Sun

Orbit Count
0

Meter Voltage [V]
15.60

Set Voltage
15.60

Meter Current [A]
0.140

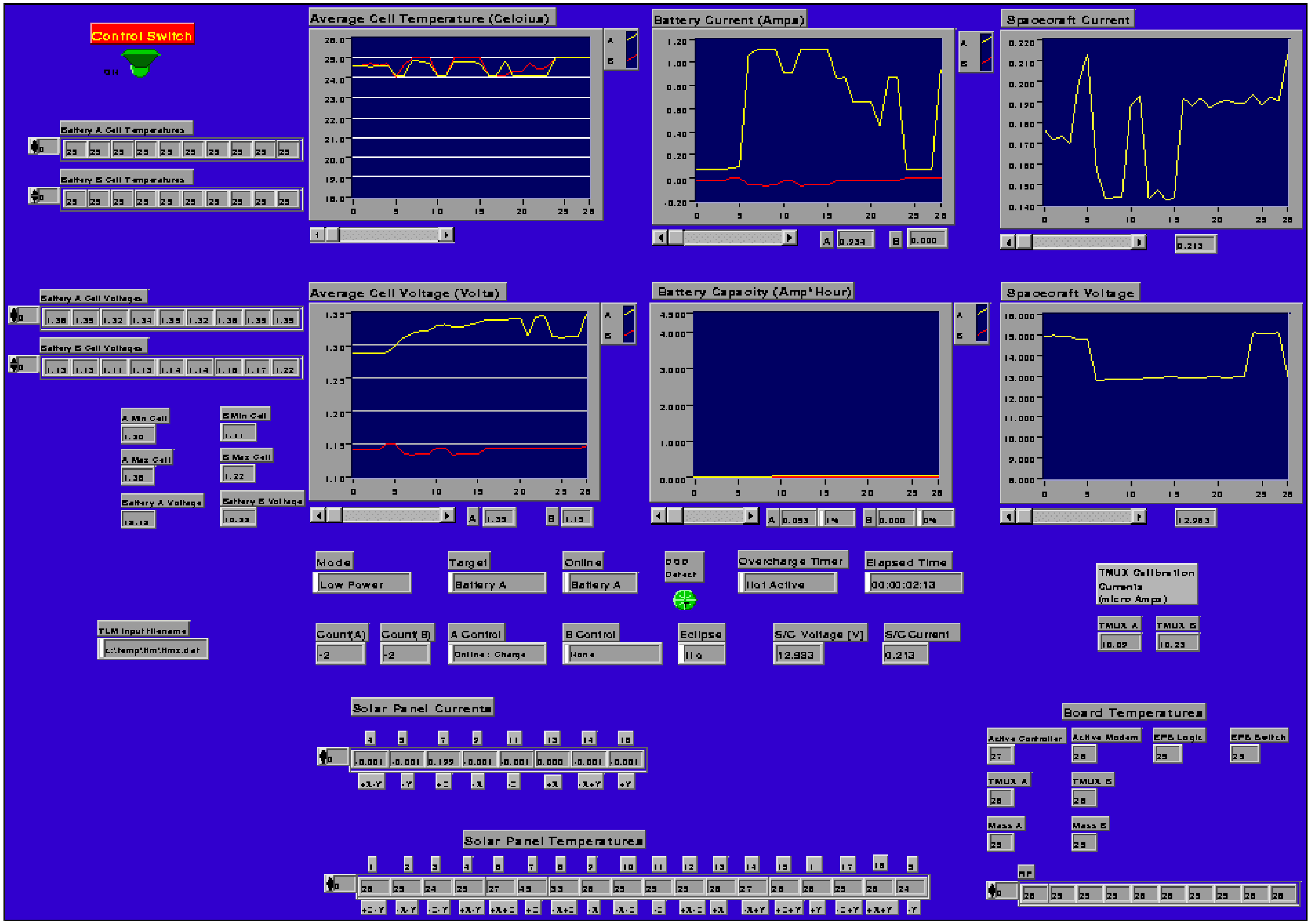
Set Current
1.400

Orbit

Spacecraft Rotation

Rotation Step
5

Monitor VI



Battery A Cell Temperatures: 25 25 25 25 25 25 25 25 25 25

Battery B Cell Temperatures: 25 25 25 25 25 25 25 25 25 25

Battery A Cell Voltages: 1.36 1.35 1.32 1.34 1.35 1.32 1.36 1.35 1.35

Battery B Cell Voltages: 1.13 1.13 1.11 1.13 1.14 1.14 1.16 1.17 1.22

A Min Cell: 1.30

A Max Cell: 1.36

B Min Cell: 1.11

B Max Cell: 1.22

Battery A Voltage: 13.13

Battery B Voltage: 10.33

Battery Current: A 0.934 B 0.000

Spacecraft Current: 0.213

Average Cell Voltage: A 1.35 B 1.15

Battery Capacity: A 0.053 1% B 0.000 0%

Spacecraft Voltage: 12.983

Mode: Low Power

Target: Battery A

Online: Battery A

Overcharge Timer: Not Active

Elapsed Time: 00:00:02:13

TLM Input Filename: c:\temp\tlm\tlmz.dat

Count(A): -2

Count(B): -2

A Control: Online : Charge

B Control: None

Eclipse: No

S/C Voltage [V]: 12.983

S/C Current: 0.213

TMUX Calibration Currents (micro Amps)

TMUX A: 10.09

TMUX B: 10.23

Solar Panel Currents

4	5	7	9	11	13	14	16
-0.001	-0.001	0.199	-0.001	-0.001	0.000	-0.001	-0.001
+X-Y	-Y	+Z	-X	-Z	+X	-X+Y	+Y

Solar Panel Temperatures

1	2	3	4	6	7	8	9	10	11	12	13	14	15	1	17	18	5
28	25	24	25	27	45	33	28	25	25	25	28	27	28	28	25	28	24
+Z-Y	-X-Y	-Z-Y	+X-Y	+X+Z	+Z	-X+Z	-X	-X-Z	-Z	+X-Z	+X	-X+Y	+Z+Y	+Y	-Z+Y	+X+Y	-Y

Board Temperatures

Active Controller: 27

Active Modem: 28

EPS Logic: 25

EPS Switch: 25

TMUX A: 28

TMUX B: 28

Mass A: 25

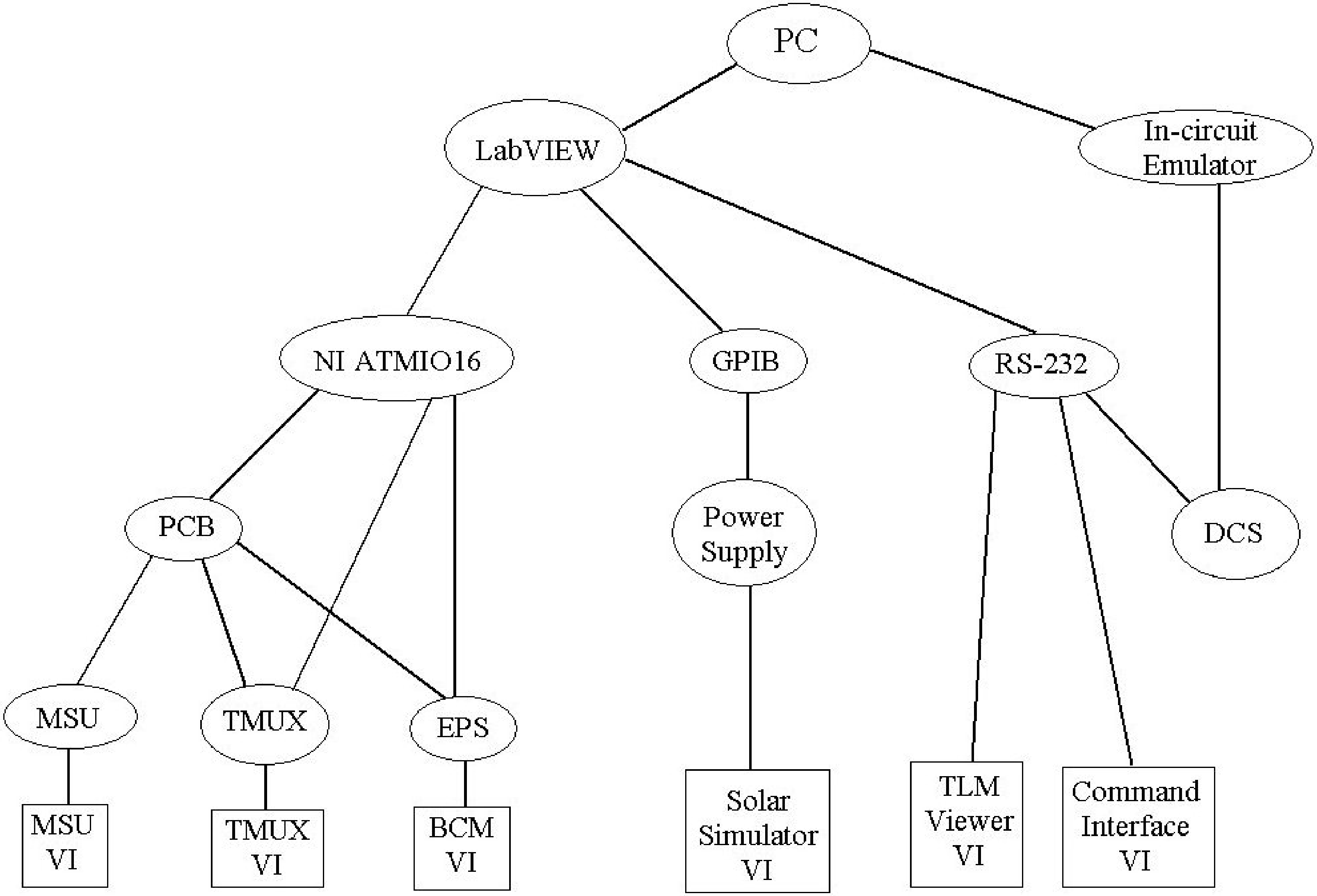
Mass B: 25

RF: 28 25 25 25 28 28 25 25 28 28

Mr. Jim A. Horning, Naval Postgraduate School

1999 Shuttle Small Payloads Project Office Symposium

Battery Charge Monitor Support Hierarchy



Migration to Spacecraft Embedded Computer

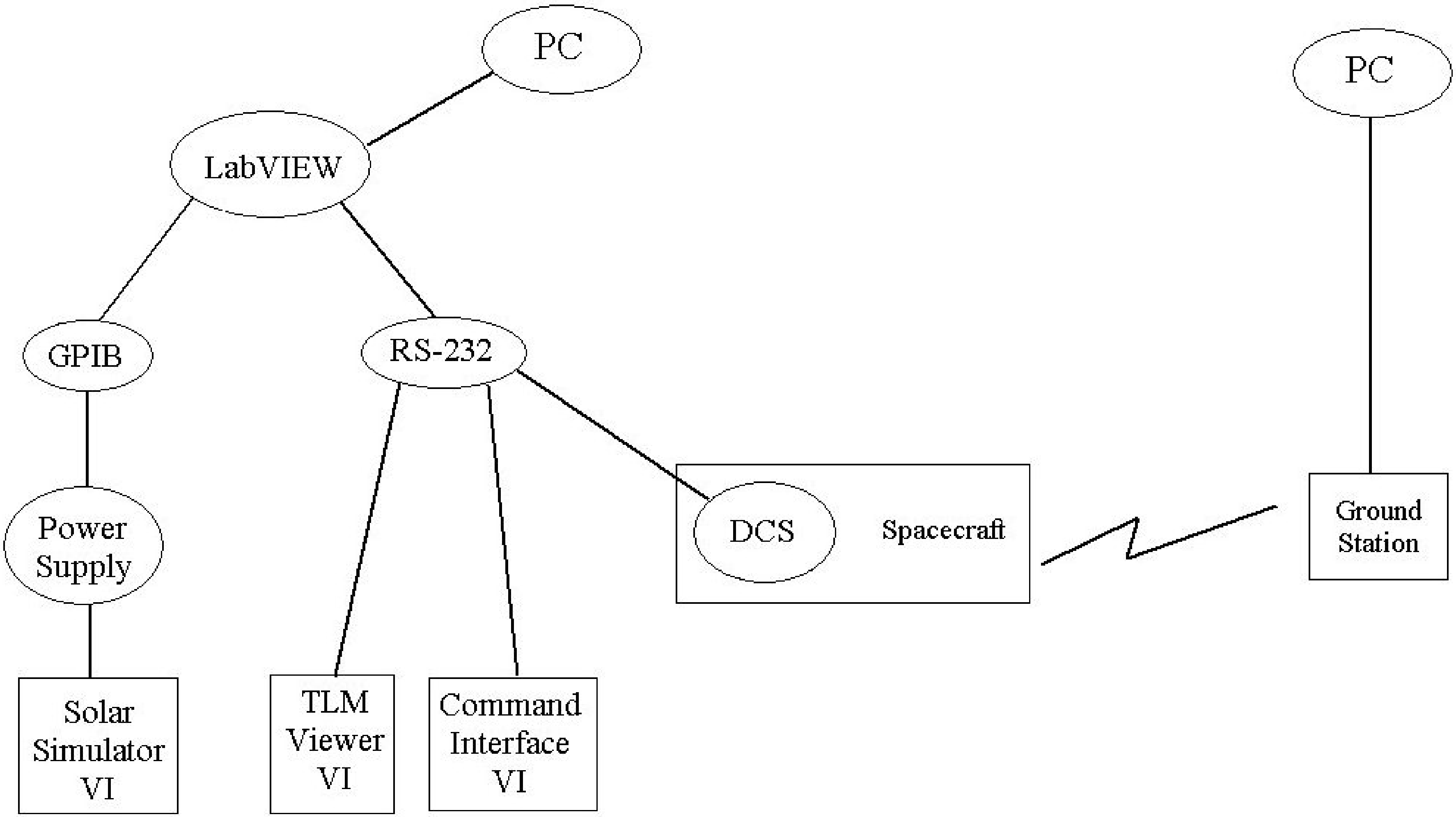
- Ported algorithms developed in LabVIEW to C
- Used RS-232 port on embedded system to PC
  - Provided command/control
  - Provided data dumping
- Removed use of A/D conversion on PC
  - Required embedded system to perform A/D
- Modified use of individual VIs for subsystem control
  - Granted the embedded system control of the spacecraft
  - Allowed VIs to send commands to spacecraft
- Created Monitor VI to allow complete viewing of spacecraft systems using data sent across the RS-232 port

Spacecraft Integration

- Support Hardware
  - Two laptop PCs
  - HP 6653A DC programmable power supply
  - Brief-case sized RF/Modem unit

- Support Software
  - Spacecraft Test Port Interface using RS-232 port
  - Command/Control Interface program
  - LabVIEW Monitor VI

Integration Support Hierarchy



Integration Tests

- Performed a suite of automated tests after each test
    - Checked spacecraft computer
    - Powered on and check subsystems and interfaces
    - Performed EPS check
        - Toggled all switches
        - Monitored all measurements
    - Performed a moving ones write/read on Mass Storage
    - Monitored TMUX measurements
    - Tested all eight Communication states with brief-case sized Modem/RF unit in low power mode
- Archived all test results (command log, graphs, data dumps) to disk

Conclusion

- PANSAT launched aboard the STS-95 *Discovery*

- PANSAT contacted daily via NPS ground station

- Testing, integrating, and operating an autonomous spacecraft can be accomplished with reusable modules using:
  - Low cost support equipment (power supply, load)
  - Low cost PCs
  - LabVIEW
  - Custom programming

- Further development of spacecraft can be performed using this simple model